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CAROTENE FROM VEGETABLE LEAF WASTES COMPARED WITH VITAMIN A IN CHICK RATIONS

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IN COOPERATION WITH
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Dried vegetable leaf wastes make excellent poultry feed supplements as has been pointed out by Tomhave and co-workers (5). Certain of these leaf wastes are particularly good as a source of pro-vitamin A or carotene and can be used in small amounts to supply all of the vitamin A needed by growing chicks. Broccoli leaf meal, for example, contains from 300,000 to 500,000 I. U. of vitamin A per pound in the form of carotene and it has been shown that in concentrations as low as 1 per cent of the diet it is an efficient source of this factor (2).

There has been some question regarding the chicken's ability to utilize the pro-vitamin A, carotene, as efficiently as the true vitamin A from fish liver oils. Ahmad and Malik (1) have stated that chickens can convert carotene into vitamin A only 24 per cent as efficiently as rats. Russell and co-workers (4) present data which show that hens absorb 50-60 per cent carotene on normal fat rations as compared to 85-96 per cent of the ester vitamin A. On the other hand Wilson and co-workers (8) state that carotene is just as efficient as vitamin A obtained from a fish oil concentrate in regards to utilization by chicks. The National Research Council (3) in its list of recommended nutrient allowances for chickens states that the vitamin A activity may be fish oil vitamin A or pro-vitamin A from vegetable sources.

Due to conflicting opinions concerning the efficiency of carotene as compared to vitamin A it was deemed advisable to determine the comparative value of carotene obtained from dried vegetable wastes with that of vitamin A. This work has been done in cooperation with the Eastern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry of the United States Department of Agriculture.

In the following feeding trials carotene, as present in the leaf meals and in the form of concentrates prepared from these meals, has been compared with vitamin A ester as it occurs in fish liver oils and in molecularly distilled fractions obtained from these oils.

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[1] Acknowledgment is made to Edmund Hoffmann, formerly Assistant Poultry Husbandman, during the period July 1, 1942 to March 1, 1945, who conducted the preliminary experiment and to C. W. Mumford, Superintendent of the Experiment Station Poultry Farm, for supervising the feeding and management details of the experiments.

PRELIMINARY EXPERIMENT

In 1944 a preliminary unpublished experiment was carried out by Hoffmann and co-workers to determine the relative value of carotene in broccoli leaf meal and in the form of a concentrate prepared from this meal. The results of this preliminary work are in line with subsequent experiments and they are of sufficient value to warrant their inclusion in this bulletin. The carotene extract used in this experiment was prepared by the method of Wall, Kelley, and Willaman (7) in which the leaf meal was extracted with petroleum ether (Skellysolve B), the extract saponified, and the carotene finally purified by absorption and elution from lime.

Ten groups of 40 Barred Rock - New Hampshire Cross chicks each were placed in a battery brooder and fed a basal ration plus various sources of carotene and vitamin A. The basal ration consisted of the following:

Ground Yellow Corn	14 pounds
Ground Oats	15
Wheat Bran	15
Cracked Wheat	23
Soybean Oil Meal	20
Meat Scrap	5
Steamed Bone Meal	1
Oyster Shell Flour	1.5
Salt Mix	.5
D-Activated Animal Sterol	.5
Dried Skim Milk	2.0
	97.05

A list of the various diets fed is found in Table 1.

It should be noted that the addition of 3 per cent dehydrated broccoli leaf meal to the basal ration increased the vitamin A content to a high level. In comparable groups this high level was maintained in order to assure similarity in vitamin A content. In Group 3 the carotene was extracted from the broccoli leaf meal in order to determine whether the chick growth was caused by the carotene or some other factor in the meal. Group 7 had distillers solubles added in order to determine whether it would increase the rate of growth of chicks. At the level of 9360 I. U. vitamin A per pound of mixed feed the regular broccoli leaf meal can be compared with extracted carotene, crystalline carotene, and fish liver oil as vitamin A or carotene sources. At the level of 1360 I. U. vitamin A per pound of mixed feed extracted carotene can be compared with fish liver oil.

At five weeks of age the birds were moved to an intermediate battery for the remaining three and a half weeks. The birds were individually weighed at 3, 6, and 8½ weeks and feed consumption and mortality were recorded weekly.

TABLE 1. SUMMARY OF RESULTS—PRELIMINARY EXPERIMENT

Group No.	Diet	Vitamin A Content	Av. Wt. of Birds			Feed Consumption per Bird for Entire Period	Feed Efficiency per Bird for Entire Period	Mortality per Group
			3 Wks.	6 Wks.	8½ Wks.*			
		I. U. per lb.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs. Feed/Lbs. Gain	No.
1	Basal	477	.480	1.141	1.781	5.43	3.19	4
2	Basal + 3 per cent broccoli leaf meal	9360	.485	1.308	2.355	6.18	2.72	6
3	Basal + 3 per cent carotene extracted broccoli leaf meal	477	.473	1.189	1.961	5.59	2.97	1
4	Same as for #3 + high level of carotene concentrate	9360	.493	1.333	2.290	6.53	2.96	2
5	Same as for #3 + commercial crystalline carotene	9360	.471	1.328	2.308	6.58	2.95	7
6	Same as for #3 + low level of carotene concentrate	1360	.512	1.348	2.205	6.01	2.83	4
7	Basal + distillers solubles + carotene concentrate	9360	.509	1.368	2.353	6.21	2.73	7
8	Same as for #3 + high level of vitamin A from fish liver oil	9360	.508	1.372	2.308	6.02	2.70	3
9	Same as for #3 + low level of vitamin A from fish liver oil	1360	.497	1.324	2.195	6.02	2.85	4

*Difference necessary for significance at the 5% level is .022 pounds and at the 1% level is .030 pounds.

Discussion of Preliminary Experiment

The summary of results is presented in Table 1. The final weights of all other groups were highly significantly superior to Group 1 (Basal Ration) and Group 3 (Basal Ration plus 3 per cent carotene-extracted broccoli leaf meal) when analyzed statistically by analysis of variance.[1] Within the groups containing 9360 I. U. of vitamin A per pound of mixed feed, the broccoli leaf meal group and the distillers solubles plus carotene concentrate group had final weights of 2.36 pounds and 2.35 pounds, respectively, and their weights were statistically highly significant over all the other groups. The two groups with 1360 I. U. of vitamin A per pound of mixed feed, Group 6 (carotene concentrate) and Group 9 (vitamin A fish oil) had average final weights of 2.21 pounds and 2.20 pounds, respectively.

The data in Table 1 on feed consumption, feed efficiency, and mortality would indicate that the source of carotene or vitamin A has no particular influence on the final results.

EXPERIMENTAL PROCEDURE

Since the preliminary experiment indicated that carotene was utilized as efficiently as vitamin A from fish liver oil it seemed desirable to conduct more precise experiments. Two separate experiments were carried out; the first, Experiment I, compared the utilization of carotene furnished by broccoli and lima bean leaf meal and carotene concentrate from vegetable waste with vitamin A esters from fish liver oil; Experiment II differed from Experiment I in sex and age of birds, and source of carotene concentrate.

Experiment I

Nine groups of 35 male chicks from a New Hampshire male Barred Rock female cross were placed in an electric battery brooder on November 7, 1946. All groups received the same management except for rations fed. A basal ration deficient in vitamin A was formulated and is presented below:

White Corn Meal	16.95 pounds
Ground Oats	15.00
Wheat Bran	15.00
Ground Wheat	23.00
Soybean Oil Meal	20.00
Meat Scraps (50%)	5.00
Dried Skim Milk	2.00
Steamed Bone Meal	1.00
Oyster Shell Flour	1.50
Salt Mix	.50
D-Activated Animal Sterol	.05
	100.00

[1] The difference necessary for significance was essentially the same when unequal numbers were considered. The differences necessary for significance given in Tables 1, 2, and 5 is the greatest difference required for significance.

To the basal ration were added varying amounts of dehydrated broccoli-lima bean leaf meal containing 0.39 mg/gm carotene and 1.0 mg/gm tocopherol, carotene from a molecular distillation of a broccoli leaf extract containing 15.0 mg/gm of carotene and 21.0 mg/gm tocopherol, and distilled vitamin A esters containing 200,000 I. U. vitamin A per gram as follows:

Group 1—Basal Ration plus dehydrated broccoli-lima bean leaf meal to give 500 I. U. vitamin A per pound of mixed feed.

Group 2—Basal Ration plus dehydrated broccoli-lima bean leaf meal to give 1500 I. U. vitamin A per pound of mixed feed.

Group 3—Basal Ration plus dehydrated broccoli-lima bean leaf meal to give 3000 I. U. vitamin A per pound of mixed feed.

Group 4—Basal Ration plus carotene concentrate to give 500 I. U. vitamin A per pound of mixed feed.

Group 5—Basal Ration plus carotene concentrate to give 1500 I. U. vitamin A per pound of mixed feed.

Group 6—Basal Ration plus carotene concentrate to give 3000 I. U. vitamin A per pound of mixed feed.

Group 7—Basal ration plus distilled vitamin A esters to give 500 I. U. vitamin A per pound of mixed feed.

Group 8—Basal Ration plus distilled vitamin A esters to give 1500 I. U. vitamin A per pound of mixed feed.

Group 9—Basal Ration plus distilled vitamin A esters to give 3000 I. U. vitamin A per pound of mixed feed.

The mashes and vitamin supplements were analyzed for carotene, tocopherol, and vitamin A by the method of Wall and Kelley (6). These values were then used to calculate the quantities of the various supplements necessary to bring the basic ration to the required carotene, tocopherol, and vitamin A levels. After mixing the vitamin supplements into the mash, it was then analyzed in order to determine the accuracy of the mixing. Owing to the inherent error involved in analyzing mashes for carotene or vitamin A at low levels of 500 to 1500 I. U. per pound, the diets at the 3000 I. U. level were used to check the mixing. In all cases results within 10 per cent of the expected values were found. Since the mashes fortified at lower levels were prepared in exactly the same manner by simple dilution of the vitamin supplements, the same degree of accuracy can be expected. The required amounts of the oils containing the various vitamins were added to a sufficient quantity of the basic ration to make exactly one pound. The oil and mash were thoroughly mixed in a large mortar and pestle so that the homogenous and dry concentrated premix was secured. This was then mixed with nine pounds of the basic ration in a small hand mixer. The 10-pound premix was finally mixed in a large, motor-driven mixer with the total quantity of mash used in each group.

The carotene concentrate used in this experiment was prepared by the extraction of leaf meal with petroleum ether, precipitation of an insoluble lipid fraction with acetone, followed by filtration and evaporation of the filtrate in the presence of a vegetable oil. The resultant oil solution was then molecularly distilled, yielding, after stripping off most of the tocopherol and sterols, a red distilled carotene concentrate and a more dilute, green residual oil containing carotene.

In order to rule out any variable due to the effect of alpha-tocopherol on the utilization of either carotene or vitamin A, it was considered advisable to have a sufficiently high level of the tocopherol present. Kish and co-workers at this Station, in unpublished experiments on tocopherol - carotene ratios, found that ratios of 25-1 were equal to or slightly better than ratios of 50 to 1 or 100 to 1. Therefore, the 25 to 1 ratio was maintained in each of the groups. At the 500 I. U. per pound levels the tocopherol content of the basic mash was sufficient to maintain this ratio. At the 1500 and 3000 I. U. per pound levels additional tocopherol[1] was added.

At six weeks of age the birds were moved to an intermediate battery where they remained until the end of the tenth week when the experiment was terminated. The birds were group weighed each week except at the completion of the experiment when they were weighed individually. Weekly feed consumption and daily mortality records were taken during the experiment.

Discussion of Experiment I.

The average weekly weights for each group are presented in Table 2. At the final weighing, Group 3, with an average of 2.87 pounds per bird, was highest and Group 7, with an average of 2.44 pounds per bird, was lowest.

Groups 1, 4, and 7, fed rations with 500 I. U. vitamin A per pound, had average weights of 2.64 pounds, 2.47 pounds, and 2.44 pounds, respectively. When the data are analyzed statistically by analysis of variance, Group I is highly significant over the other two groups, while the difference between Groups 4 and 7 is not significant.

Groups 2, 8, and 5, fed rations containing 1500 I. U. of vitamin A, had average weights of 2.84 pounds, 2.83 pounds, and 2.78 pounds, respectively. Both Groups 2 and 8 have highly significant weight differences over Group 5 when the data are analyzed statistically.

Groups 3, 6, and 9, fed rations containing 3000 I. U. of vitamin A, had average weights of 2.87 pounds, 2.84 pounds, and 2.84 pounds, respectively. The differences between the various groups are not significant.

Feed consumption records are presented in Table 3. Consumption per bird varies from a high of 9.41 pounds in Group 8 to a low of 8.25 pounds in Group 7. It is interesting to note that in most of the groups that total feed consumption per bird increases as the level of carotene or vitamin A is increased.

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[1] A concentrate of natural mixed tocopherols distilled from vegetable oils, and containing 34% mixed tocopherols, secured from Distillation Products, Inc.

TABLE 2. AVERAGE WEEKLY BODY WEIGHT PER BIRD—EXPERIMENT I

Week	Groups*								
	Broccoli - Lima Bean Leaf Meal			Carotene Concentrate			Vitamin A Esters		
	1	2	3	4	5	6	7	8	9
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Initial	.083	.086	.083	.083	.080	.083	.086	.080	.086
1	.14	.14	.15	.15	.14	.15	.15	.13	.15
2	.27	.27	.27	.27	.26	.27	.28	.27	.28
3	.47	.48	.48	.47	.45	.50	.49	.49	.50
4	.67	.67	.69	.65	.62	.67	.67	.69	.68
5	.82	.85	.90	.79	.87	.89	.83	.95	.94
6	1.15	1.22	1.29	1.13	1.25	1.26	1.15	1.32	.1.32
7	1.50	1.61	1.68	1.45	1.64	1.64	1.46	1.71	1.73
8	1.92	2.05	2.13	1.80	2.06	2.06	1.83	2.14	2.17
9	2.24	2.42	2.44	2.12	2.43	2.42	2.12	2.48	2.42
10**	2.64	2.84	2.87	2.47	2.78	2.84	2.44	2.83	2.84

*Groups 1, 2, and 3 received carotene equivalent to 500, 1500, and 3000 I. U. of Vitamin A per pound.
Groups 4, 5, and 6 " " " " " " " " " " " " " " " "
Groups 7, 8, and 9 received 500, 1500, and 3000 I. U. of Vitamin A per pound.

**Difference necessary for significance at the 5% level is .034 pounds and at the 1% level is .047 pounds.

TABLE 3. WEEKLY FEED CONSUMPTION PER BIRD—EXPERIMENT I

Week	Groups*								
	Broccoli - Lima Bean Leaf Meal			Carotene Concentrate			Vitamin A Esters		
	1	2	3	4	5	6	7	8	9
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1	.16	.16	.15	.16	.16	.16	.17	.17	.16
2	.27	.28	.29	.28	.27	.30	.31	.28	.29
3	.54	.52	.52	.50	.51	.56	.52	.53	.54
4	.55	.53	.54	.52	.53	.56	.54	.56	.55
5	.64	.70	.72	.59	.67	.73	.61	.76	.74
6	.97	1.07	1.18	.92	1.08	1.13	.97	1.09	1.12
7	1.12	1.17	1.26	1.06	1.21	1.25	1.05	1.28	1.28
8	1.35	1.38	1.44	1.31	1.32	1.40	1.26	1.51	1.52
9	1.32	1.49	1.44	1.37	1.50	1.48	1.28	1.49	1.38
10	1.63	1.74	1.82	1.59	1.66	1.82	1.54	1.74	1.77
Total	8.55	9.04	9.36	8.30	8.91	9.39	8.25	9.41	9.35

*Groups 1, 2, and 3 received carotene equivalent to 500, 1500, and 3000 I. U. of Vitamin A per pound.
Groups 4, 5, and 6 " " " " " " " " " " " " " " " "
Groups 7, 8, and 9 received 500, 1500, and 3000 I. U. of Vitamin A per pound.

TABLE 4. POUNDS OF FEED REQUIRED PER POUND OF ACTUAL GAIN—EXPERIMENT I

Week	Groups*								
	Broccoli - Lima Bean Leaf Meal			Carotene Concentrate			Vitamin A Esters		
	1	2	3	4	5	6	7	8	9
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1	2.81	2.96	2.24	2.39	2.67	2.39	2.66	3.40	2.50
2	2.08	2.15	2.42	2.33	2.25	2.50	2.38	2.00	2.23
3	2.70	2.48	2.48	2.50	2.68	2.43	2.48	2.41	2.45
4	2.75	2.79	2.57	2.89	3.12	3.29	3.00	2.80	3.06
5	4.27	3.89	3.43	4.21	2.68	3.32	3.81	2.92	2.85
6	2.94	2.89	3.03	2.71	2.84	3.05	3.03	2.95	2.95
7	3.20	3.00	3.23	3.31	3.10	3.29	3.39	3.28	3.12
8	3.21	3.14	3.20	3.74	3.14	3.33	3.41	3.51	3.45
9	4.13	4.03	4.65	4.28	4.05	4.11	4.41	4.38	3.94
10	4.08	4.14	4.23	4.54	4.74	4.33	4.81	4.97	4.21
Entire Period	3.34	3.29	3.35	3.47	3.30	3.40	3.51	3.42	3.40

*Groups 1, 2, and 3 received carotene equivalent to 500, 1500, and 3000 I. U. of Vitamin A per pound.
Groups 4, 5, and 6 " " " " " " " " " " " " " "
Groups 7, 8, and 9 received 500, 1500, and 3000 I. U. of Vitamin A per pound.

Feed efficiency as shown by pounds of feed required to produce a pound of actual gain is presented in Table 4. The most efficient feed utilization was in Group 2 which required 3.29 pounds of feed to produce a pound of gain, while the poorest feed efficiency was in Group 7 which required 3.51 pounds.

Group 8 had the highest mortality (4 birds) followed by Groups 4 and 6 with three birds each, Group 2 with two birds, and Groups 1, 3, 5, 7, and 9 with one bird each.

Experiment II

To further substantiate previous results, Experiment II was organized to be in many respects a duplication of Experiment I. This experiment was started February 6, 1947 and continued until May 1, 1947. The same experimental procedure, basal ration, supplements, and levels were used. The only differences were as follows:

1. Each group consisted of 15 male and 15 female New Hampshire male Barred Rock female cross chicks instead of all male chicks.
2. The birds were raised to 12 weeks of age instead of 10 weeks.
3. The carotene concentrate was prepared by the molecular distillation process described in Experiment I, but, instead of using the red distilled oil which represents the first carotene fraction, the green oil remaining in the still after distillation was used. This oil contains undistilled carotene (2.9 mg/gm), tocopherol (1.5 mg/gm), as well as xanthophyll, chlorophyll, and other lipoid materials.

Discussion of Experiment II.

A summary of the results obtained is presented in Table 5. Since the data were similar to that presented in Experiment I only the final weights, the total feed consumption, and feed efficiency figures per bird are listed. Groups 1, 4, and 7, fed rations with 500 I. U. of vitamin A per pound of mixed feed, had average weights of 2.45 pounds, 2.26 pounds, and 2.16 pounds, respectively. Groups 5, 2, and 8, fed rations containing 1500 I. U. of vitamin A, had average weights of 3.03 pounds, 2.80 pounds, and 2.72 pounds, respectively. Groups 9, 3, and 6, fed rations containing 3000 I. U. of vitamin A, had average weights of 2.95 pounds, 2.92 pounds, and 2.81 pounds, respectively.

In most cases, feed consumption per bird increased as the level of carotene or vitamin A was increased. At a given level there was no great difference between the carotene and vitamin A groups in feed consumption. All the groups receiving 500 I. U. of vitamin A had the poorest feed efficiency within their respective classes.

Storage of Vitamin A in Chick Livers

At the conclusion of Experiment II, two male and two female chicks from each nutritional group were sacrificed and the livers re-

TABLE 5. SUMMARY OF RESULTS—EXPERIMENT II

Group No.	Diet	Vitamin A Content	Average Weight of Birds - 12 wks. Weighted Average of Sexes*	Feed Consumption per Bird for Entire Period	Feed Efficiency per Bird for Entire Period	Mortality per Group
		I.U.per Lb.	Lbs.	Lbs.	Lbs. Feed/Lb. Gain	No.
1	Basal+Broccoli-Lima Bean Leaf Meal	500	2.45	8.80	3.72	7
2	Basal+Broccoli-Lima Bean Leaf Meal	1500	2.80	9.43	3.48	2
3	Basal+Broccoli-Lima Bean Leaf Meal	3000	2.92	10.16	3.58	2
4	Basal+Carotene Concentrate.....	500	2.26	8.26	3.80	4
5	Basal+Carotene Concentrate.....	1500	3.03	10.24	3.48	4
6	Basal+Carotene Concentrate.....	3000	2.81	9.97	3.66	3
7	Basal+Vitamin A Esters.....	500	2.16	8.00	3.85	4
8	Basal+Vitamin A Esters.....	1500	2.72	9.73	3.70	1
9	Basal+Vitamin A Esters.....	3000	2.95	9.94	3.47	3

*Difference necessary for significance at the 5% level is .058 pounds and at the 1% level is .079 pounds.

moved. The livers were ground in a Waring Blender, saponified with alcoholic KOH, and, after dilution with water, the alcoholic solution was extracted with ether. The ethereal extracts were analyzed for vitamin A, total carotenoids, and carotene. The results are shown in Table 6.

From the data it is apparent that the storage of vitamin A in the liver was proportional to the quantity of carotene or vitamin A in the ration. In this connection it is of interest that the group to which carotene was supplied as a concentrate apparently stored as much vitamin A in the livers as those to which vitamin A was supplied directly. On the other hand, the birds supplied with carotene in the form of a leaf meal did not store as much vitamin A at the 1500 and 3000 I. U. per pound levels as the other groups. Nevertheless, the growth characteristics of the leaf meal group were equal to those of the carotene concentrate and vitamin A groups. The total carotenoid and carotene contents of the livers were, as might be expected, roughly proportional to the carotene intake. As with the storage of vitamin A, the groups receiving carotene concentrate had higher levels of carotenoids and carotene than the leaf meal series.

TABLE 6. VITAMIN A, TOTAL CAROTENOID, AND CAROTENE CONTENTS OF LIVERS FROM BIRDS

Group*	Vitamin A I. U./Liver	Total Carotenoids mcg/Liver	Carotene mcg/Liver
1	43	15	3
2	180	33	8
3	945	67	21
4	54	16	8
5	528	44	24
6	2620	80	28
7	47	0	0
8	428	0	0
9	2820	0	0

*Groups 1, 2, and 3 received carotene equivalent to 500, 1500, and 3000 I. U. of vitamin A per pound from leaf meal.

Groups 4, 5, and 6 received carotene equivalent to 500, 1500, and 3000 I. U. of vitamin A per pound from carotene concentrate.

Groups 7, 8, and 9 received 500, 1500, and 3000 I. U. of vitamin A per pound.

SUMMARY

Three experiments were run to determine the efficiency of carotene from dehydrated vegetable wastes as compared to vitamin A esters from fish oil in chick rations. The carotene was supplied in both the form of leaf meal and a concentrate.

GROWTH.—The results indicate that, depending upon the level of carotene or vitamin A esters furnished, carotene is as efficient if not superior to vitamin A esters. The final weights obtained in the 1500 and 3000 I. U. of vitamin A groups from the last two experiments are listed below:

Group	1500 I. U. Vitamin A		3000 I. U. Vitamin A	
	Exp. I Lbs.	Exp. II Lbs.	Exp. I Lbs.	Exp. II Lbs.
Broccoli-Lima Bean Leaf Meal	2.84	2.80	2.87	2.92
Carotene Concentrate	2.78	3.03	2.84	2.81
Vitamin A Esters	2.83	2.72	2.84	2.95

It should be noted that Experiment I was composed of all males and ran for 10 weeks while Experiment II was composed of an equal number of both sexes and ran for 12 weeks.

FEED CONSUMPTION AND EFFICIENCY.—Generally speaking the feed consumption per bird increased as the level of carotene or vitamin A ester was increased. At a given level there appeared to be no difference between the carotene or vitamin A ester groups. The feed consumption in Experiments I and II are listed below:

Group	1500 I. U. Vitamin A		3000 I. U. Vitamin A	
	Exp. I Lbs.	Exp. II Lbs.	Exp. I Lbs.	Exp. II Lbs.
Broccoli-Lima Bean Leaf Meal	9.04	9.43	9.36	10.16
Carotene Concentrate	8.91	10.24	9.39	9.97
Vitamin A. Esters	9.41	9.73	9.35	9.94

All three groups receiving 500 I. U. of vitamin A had the poorest feed efficiency within their respective classes in both the last two experiments. At a given level there is no great difference in feed efficiency between the carotene or vitamin A ester groups.

CONCLUSION

Carotene from dehydrated vegetable waste, either in the form of the vegetable waste meal or as a concentrate, is just as efficient as vitamin A esters from fish liver oil in sustaining chick growth.

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